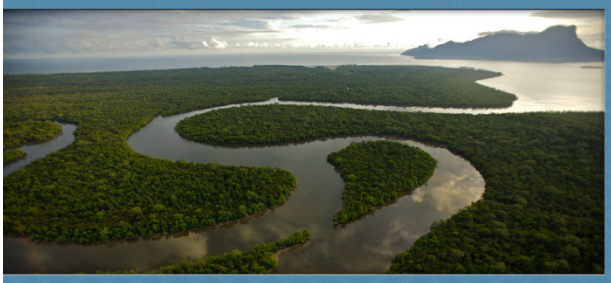
Bay of Bengal Large Marine Ecosystem Project



Report of the

Training workshop on the application of Ecopath with Ecosim to BOBLME

8-12 September 2014 Phuket, Thailand

BOBLME-2014-Ecology-08

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Report of the Training workshop on the application of Ecopath with Ecosim (EwE) to the Bay of Bengal Large Marine Ecosystem (BOBLME)

Phuket, Thailand, 8th-12th September 2014

Resource consultants

Dr Villy Christensen and Dr Sylvie Guénette

Executive summary

The workshop was held in Phuket, Thailand during 8-12 September 2014, with 19 experts representing the eight countries that participate in the Bay of Bengal Large Marine Ecosystem Project (BOBLME). The objective was to engage the experts to verify, validate and provide information to improve a regional BOBLME model, which was developed in collaboration with experts from the University of British Columbia's Fisheries Centre. The Ecopath with Ecosim (EwE) model and supporting documentation were made available to the participants before the workshop as well as on the web site of the workshop.

The workshop was organised around lectures describing the basis and principles underlying the software, and tutorials designed to familiarise the participants with the software itself. The program encompassed all subjects from the basics of Ecopath to Ecospace, economics, and management strategy evaluation. At each appropriate step of the software presentation, the link was made with the BOBLME model by presenting the relevant part of the model (e.g., data, structure, times series, behaviour). At each presentation, participants were invited to comment and contribute information to improve the model. These sessions were indeed supportive of the BOBLME initiative through the widespread offers to share data sets and recommendations that were made to improve the model. This also provides an important support for development of regional capacity and cooperation on data analyses and Modelling.

The workshop was successful in two major ways. First, it achieved the goal to familiarise the participants with the software and its capabilities. The ambitious program had the advantage of opening up new possibilities to address management issues identified by local experts. Second, the workshop allowed participants to see how they could contribute to the BOBLME model and, perhaps more importantly, how they could use ecosystem modelling in national or sub-regional modelsz to address local issues. The discussions sometimes led to interesting projects requesting collaboration between countries. These sub-regional models could also be used to inform the regional model that will continue to be improved. A list of possible contributions to the model was compiled.

At the start of the workshop, most participants had very little knowledge of the Ecopath with Ecosim software. The vast majority of the participants were very satisfied with the workshop and progress, but as must be expected for a challenging workshop with new materials, some found that subjects were presented too fast and a majority did not feel comfortable at the end of the workshop with the idea of starting a new model on their own. To this end, it was recommended that support be given to participants to build their sub-regional models and that a workshop be organised within the next half year.

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Acronyms used

BOB	Bay of Bengal
BOBLME	Bay of Bengal Large Marine Ecosystem
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
ICES	International Council for the Exploration of the Sea
LME	Large Marine Ecosystem
MPA	Marine Protected Area
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
PEST	Political, Economic, Social and Technological analysis
SAUP	Sea Around Us Project
SRA	Stock Reduction Analysis
UBC	University of British Columbia
CMFRI	Central Marine Fisheries Research Institute
NARA	National Aquatic Resources Research and Development Agency
IOTC	Indian Ocean Tuna Commission
UNDP	United Nations Development Programme
CPUE	Catch Per Unit Effort

1. Introduction

The workshop was held in Phuket, Thailand during the period 8-12 September 2014, with the participation of 19 local experts from the eight countries that participate in the Bay of Bengal Large Marine Ecosystem Project (BOBLME) and was facilitated by two lecturers, who both have considerable experience in ecosystem modelling (see the list of participants in Appendix 1). Some of the participants had previous experience with ecosystem Modelling, but for the majority of the participants it was a new challenge to work with ecosystem modelling – (see the pre-workshop survey in **Appendix III**). The workshop aimed at engaging the experts to verify, validate and provide information to improve the BOBLME model developed in collaboration with experts from the University of British Columbia's Fisheries Centre.

The workshop was organised around lectures describing the basis and principles underlying the software, and tutorials designed to familiarise participants with the open source Ecopath with Ecosim (EwE) approach and software. The program encompassed all subjects from the basics of Ecopath to Ecospace, economics, and management strategy evaluation. The structure of the BOBLME model, the data used to build the model, the gaps in data, and the behaviour of the model in fitting and fisheries management modules were presented at the appropriate section of the program to foster better understanding of the BOBLME model, and to foster discussions. At the end of the workshop, local experts were able to make interesting suggestions about the regional model and sub-regional models, using a variety of EwE features and modules.

2. Organisation and materials

Dr Chris O'Brien, the Regional Coordinator of the BOBLME project, convened the workshop. Two lecturers with considerable experience with ecosystem modelling led the workshop:

Dr Villy Christensen, Professor and Co-Director of the UBC Fisheries Centre, Vancouver BC, Canada, and,

Dr Sylvie Guénette, EcOceans, St. Andrews NB, Canada.

A dedicated website, developed beforehand for the workshop, presented the agenda, and allowed downloading directly and in advance of the presentations, the tutorials, the model and supporting material, and the reading material (http://sites.google.com/site/boblmeewecourse/). The website was updated continuously to reflect changes and modifications resulting from discussions, daily progress and needs (Appendix 2). In addition to the material provided on the website (see the list below), Dr Christensen provided the participants with an electronic collection of 400 papers describing ecosystem models with a focus on EwE.

List of material available on the website

2.1. Presentations

1. Modelling marine ecosystems: Lessons learned
2. EwE6 introduction
3. Ecopath equations
4. Overview of BOBLME Ecopath model, basic input parameters
5. Natural mortality estimation (by Amy Then)
6. Exploring the BOBLME Ecopath model incl. natural mortality estimates
7. Ecopath parameters
8. Mass-balancing
9. Network analysis, incl. Mixed Trophic Impacts
10. Widely distributed species in the BOBLME model
11. Time dynamic modelling, Ecosim
12. Time series fitting and environmental parameters
13. Time series for Ecosim [for the BOBLME model]
14. From sea to consumer: modelling food webs and the economic value chain
15. Spatial modelling; Introduction to habitat capacity modelling, zoning & MPAs
16. Presentation of Management Strategy Evaluation (MSE)

2.2. Regional model and supporting material

- BOBLME model database: *BOBLME 5sep2014.zip*
- BOBLME Model Description: *Bengal report 27aug2014 net.pdf*
- BOBLME Appendix 4 of the model description report (on natural mortality): *BOBLME Appendix 4 net.xlsx*
- BOBLME User Guide: User guide 27aug2014.pdf
- Draft report on the catch reconstruction: *Zeller 2013 BOBLME_CatchReport_Oct-17-2013.pdf*
- Reconstruction of fishing effort in India, 1950-2005: *Brajgeet Bhathal 's PhD thesis 2014*
- BOBLME model times series *3dec2013minimal.csv* and *time series 3dec2013minimal.csv*

2.3. Tutorials

1. Build and parameterize an ecosystem model (Tutorial 1)

2. Mass-balancing of simple ecosystem models (Tutorial 2)
3. Fitting to time series data (Anchovy Bay) (Tutorial 3)
4. Spatial model of Anchovy Bay (Tutorial 4)
5. Management Strategy Evaluation (MSE)

2.4. Reading material

1. Ahrens, R. N. M., Walters, C. J., and Christensen, V. 2012. Foraging arena theory. Fish and Fisheries, 13:41-59.
2. Christensen, V., Coll, M., Steenbeek, J., Buszowski, J., Chagaris, D., and Walters, C. 2014a. Representing variable habitat quality in a spatial food web model. In: Springer US, Ecosystems: 1-16.
3. Christensen, V., de la Puente, S., Sueiro, J. C., Steenbeek, J., and Majluf, P. 2014b. Valuing seafood: The Peruvian fisheries sector. Marine Policy, 44(0):302-311.
4. Christensen, V., Ferdaña, Z., and Steenbeck, J. 2009. Spatial optimization of protected area placement incorporating ecological, social and economical criteria. Ecological Modelling, 220:2583-2593.
5. Christensen, V., and Pauly, D. 1992. Ecopath II- a software for balancing steady-state ecosystem models and calculating network characteristics. Ecological Modelling, 61:169-185.
6. Christensen, V., Steenbeek, J., and Failler, P. 2011. A combined ecosystem and value chain modeling approach for evaluating societal cost and benefit of fishing. Ecological Modelling, 222(3):857-864.
7. Christensen, V., and Walters, C. J. 2004. Trade-offs in ecosystem-scale optimization of fisheries management policies. Bulletin of Marine Science, 74:549-562.
8. Christensen, V., and Walters, C. J., 2011. Progress in the use of ecosystem modeling for fisheries management. In: Ecosystem approaches to fisheries: A global perspective. pp. 189-205, Ed. by V. Christensen and J. Maclean, Cambridge University Press, Cambridge.
9. Pauly, D., Christensen, V., and Walters, C. 2000. Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. ICES Journal of Marine Science, 57:697-706.
10. Walters, C., and Kitchell, J. F. 2001. Cultivation/depensation effects on juvenile survival and recruitment: implications for the theory of fishing. Canadian Journal of Fisheries and Aquatic Sciences, 58:39-50.
11. Walters, C., Pauly, D., and Christensen, V. 1999. Ecospace: Prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. Ecosystems, 2:539-554.
12. Walters, C., Pauly, D., Christensen, V., and Kitchell, J. F. 2000. Representing density dependent consequences of life history strategies in aquatic ecosystems: EcoSimII. Ecosystems, 3:70-83.
13. Walters, C. J., Christensen, V., Martell, S. J., and Kitchell, J. F. 2005. Possible ecosystem impacts of applying MSY policies from single-species assessment. ICES Journal of Marine Science, 62:558-568.
14. Walters, C. J., Christensen, V., and Pauly, D. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Reviews in Fish Biology and Fisheries, 7:139-172.

3. Program narrative

3.1. Day 1. Monday 8 Sept. 2014, 9:00-17:00

Opening: Dr Chris O'Brien opened the workshop with a brief presentation about the context for the workshop and its aim. The Bay of Bengal Large Marine Ecosystem (BOBLME) project is a collaborative effort between the United Nations Food and Agriculture Organization (FAO) and the eight countries bordering the Bay of Bengal, and is designed to improve regional management of fisheries and the marine environment. The objective of this project is to put in place the conditions to secure a healthy ecosystem and sustainability of living resources for the benefit of the coastal populations of the Bay of Bengal Large Marine Ecosystem. The project is divided into five modules: 1. Productivity indicators; 2. Socio-economics; 3. Governance indicators; 4. Fish and Fisheries indicators; 5. Pollution and ecosystem health indicators. There are 10 areas of work, among which: Identifying the major transboundary issues and their causes, and developing a plan to address them, Fisheries Resource assessment and management, Marine Protected Areas, Critical habitat management, Policy harmonisation, and Ocean dynamics, productivity and climate change, are more particularly underlying the objectives of this workshop. The project is expected to improve governance, capacity development, more regional cooperation, and an enhanced knowledge-based approach. Already two major reports have been published: 1. a transboundary diagnosis analysis, reporting on the major transboundary issues and their causes; and 2. a strategic action program to address the transboundary issues.

The present workshop is part of a series of steps to strengthen capacity for ecosystem-based management approaches which includes the development of tools allowing to gain insights in ecosystem functioning and the impact of fishing on ecosystem structure. To this end, BOBLME and the University of British Columbia collaborated on two projects, one on catch reconstruction for each of the BOBLME countries, and one for the development of a Bay of Bengal regional ecosystem model. This model will enable the exploration of fisheries management scenarios and their effects on different species groups, with emphasis on hilsa, Indian mackerel and sharks. The workshop aims to engage experts from the Bay of Bengal region to verify, validate, and where necessary provide information to improve the model.

Following the opening talk, Villy Christensen gave a welcome and introduction to the workshop, and the participants were next invited to present themselves and their expectations about the workshop. Participants generally expected to increase their knowledge and understanding of the software Ecopath with Ecosim (EwE) enough to be able to make their own model to address the fisheries management issues in their own country. The participants were also invited to fill a questionnaire designed to give the lecturers an overview of the background on data analysis, ecosystem modelling, and previous experience on EwE (see the result in the following section) in order to better target the progress of the workshop.

The technical session started at 10:30 with an overview of the EwE approach which mainly talked about the principle behind ecosystem modelling, the background on ecosystem modelling, and the link between Ecopath (the snapshot image of the ecosystem) and Ecosim (the dynamic temporal simulations). This was followed with an Introduction to Ecopath and Ecosim, its development, the structure of EwE6, the principle of mass-balance, and the master equations. After lunch, participants were invited to use EwE by building a simple model using provided data and calculating several parameters (Tutorial 1).

3.2. Day 2. Tuesday 9 Sept. 2014, 9:00-17:00

The day started with a summary of the previous day and answering questions followed by a short presentation of the Ecopath master equations, and the description of the parameters required to build an ecosystem model. The rest of the morning was dedicated to an overview of the regional model of the Bay of Bengal. The model structure, the data used for catches and biomass were

described. In addition, the participants were invited to consult and comment the draft report on catch reconstruction provided by the authors under the condition of not distributing the draft document. Special attention was given to the computation of natural mortality, a parameter often overestimated. To this end, the results of two methods were compared (and compiled in Appendix 4) and contrasted with an example from previous models. Dr Amy Then, professor at the University of Malaya, briefly described the results of her research, comparing various methods of calculating natural mortality, and recommended the use of empirical relationships based on age rather than on somatic growth rate. These results have been recently published, and a link to the paper on the ICES Journal of Marine Science website was provided on the workshop website.

The afternoon was dedicated to the principle behind mass-balancing. The first presentation formally described the basic parameters, their place in the Ecopath master equations, and methods to obtain them. The pedigree, a method to assess the quality of the data and the level at which the model is rooted in local data, was described. The second presentation described the criteria for balancing a model, and gave hints to detect which parameters are problematic, possible solutions and the rationale behind this. The participants were then invited to use Tutorial 2, to practice mass-balancing the model built in Tutorial 1, with the help of a "cheat sheet" explaining the procedure and rationale for the changes made to the model in the process of balancing it. At the end of the afternoon, the Mixed Trophic Impacts, a component of network analysis, was described and illustrated for the Bay of Bengal model.

3.3. Day 3. Tuesday 10 Sept. 2014, 9:00-17:00

The day started with a presentation on the problems encountered in building the regional model, particularly with the allocation of biomass and diets across the three regions of the Bay of Bengal for widely distributed species and a request to contribute additional data to inform the model. Several practical questions were answered during this session:

- for Indian mackerel, it can be assumed that the biomass would be allocated regions 2 and 3 proportionally to the catch
- juvenile tuna tend to aggregate in the Maldives and along the coast of Indonesia
- 10% hilsa biomass should be allocated to region 3 (instead of 2% used in the current model)

Participants commented that it would be more practical to start from national models for which there would be better information. This led to a wider discussion about the participants' interests in developing national or sub-regional models and address local issues. For instance, the issues regarding hilsa and similar species would be addressed better in a sub-regional model including Bangladesh and the north coast of Myanmar. Thus, participants were invited to state what area they would want to model, the issues they would like to address and the data available for their model and/or to contribute to the regional model. Most participants were interested in building sub-regional models to address fisheries issues and contribute data to the regional model (See **4**, first roundtable).

The rest of the day (10:30 to 17:00) was devoted to Ecosim and divided in three parts: 1. a presentation on the foraging arena, a key feature of Ecosim dynamics; 2. a presentation on the principles and approaches for fitting the model to time series; and 3. a tutorial on fitting time series. The tutorial on fitting time series also included a section on the Stock Reduction Analysis (SRA) feature that allows the use of catches to estimate biomass within Ecosim.

3.4. Day 4. Tuesday 11 Sept. 2014, 9:00-17:00

In the first half of the morning, the time series (catch, biomass and effort time series) used in the Bay of Bengal model were presented and discussed in terms of their qualities and flaws, and the possibility of obtaining more time series in the future. Indian colleagues noted that the Indian effort time series used in the model was overestimated and did not account for the observed decline in the

trawling fleet in the last decade. Participants of other countries also informed the group of the possibility of obtaining effort for their own countries.

Returning to learn more about Ecosim, the Bay of Bengal model, already fitted to time series, was used to explore the fitting results and the use of several modules in Ecosim related to fisheries management: 1. Monte Carlo simulations; 2. MSY estimation and the impact on the ecosystem. The limits and caveats of these methods (e.g., the impact of large unexplained mortality) were explained.

The exploration of the BOB model led to remarks on the composition of sharks, functional groups, which should be divided in large and small species, and into juveniles and adults to reflect the changes in habitat with age. Also, hilsa would be modelled more adequately if juveniles were considered separately given their freshwater habitat.

The second half of the morning was used to present the approach for accounting for social and economic aspects in Ecosim. Using the software, the costs and profits can be followed from the fishing boat to the consumer. This was illustrated by showing an analysis of the Peruvian upwelling ecosystem, a study that was recently published[1].

The afternoon was spent on spatial modelling (Ecospace), starting with a presentation of Ecospace structure and capabilities (including the evaluation of fishery closures), and a directed tutorial in which participants were invited to follow the experts demonstrating the various steps required to build an Ecospace model.

3.5. Day 5. Tuesday 12 Sept. 2014, 9:00-13:30

The principles and possibilities of the module: “Management strategy evaluation” (MSE) illustrated with a study on the Peruvian ecosystem. This was followed by a demonstration in which participants were guided through the menus and options to clarify the theoretical part, and run several procedures. Participants were invited to return to this tutorial and all others to deepen their understanding.

The second part of the session was meant for sharing ideas about future modelling work in the Bay of Bengal. During the roundtable (**4**, second roundtable), participants shared their modelling project and the questions they wanted to address. The description of modelling projects was generally similar to that of the first roundtable except for a few cases where the project was better defined. For instance, it became clear that several models would need to be spatially structured using Ecospace. It was noted that in the case of large scale issues such as climate change, the only appropriate model would be that of the entire LME since national or sub-regional models could not account for fish displacements. Thus, the sub-regional models could be used to inform the BOBLME model that could be used for climate change issues.

During the discussion, the need to define clear objectives was emphasised. It was also mentioned that it is possible to obtain fish distribution and habitat preferences from surveys to successfully build an Ecospace model.

Given that the sub-regional models would demand a large amount of work, it was recommended that the participants start working on the sub-regional models as soon as possible. They would continue to get technical help from the experts by email, and the same groups of participants and experts would reconvene in 2015 to refine the models and work with them, provided that a funding mechanism for this can be identified through the BOBLME.

[1]Christensen, V., De la Puente, S, Sueiro, J.C., Steenbeek, J., 2014. Valuing seafood: The Peruvian fisheries sector. Mar. Policy 44, 302–311.

3.6. Closing talk

Dr O'Brien emphasised that the workshop was a useful step towards ecosystem-based management and was glad to see the clear intentions of continuing with the modelling work. The suggestion to make national or sub-regional ecosystem models to answer specific fisheries management questions was welcome as the mandate of the project is clearly about fisheries management. Collaborations between countries to address common issues over straddling stocks or common fisheries issues are encouraged. However, it is equally clear that the objective of the BOBLME project was to look at the entire Bay of Bengal to consider large-scale issues, such as the management of sharks and global warming.

Dr O'Brien announced that the BOBLME project would support the ecosystem modelling work in two ways. Technical support to complete sub-regional models will be available through email contact with/through Sylvie Guénette. The results of other facets of the BOBLME project, such as that of the habitat characterisation project, showing habitat strata around the Bay could be useful for the modelling of the Bay of Bengal. The participants will be invited to a second workshop (possibly in March 2015) to refine and work with sub-regionals models as well as the regional BOBLME model.

The closing ceremony was held at 13h00, followed by hand-out of certificates to each of the participants.

4. Possible contributions and Ecopath modelling in the Bay of Bengal as stated at the first (A) and second (B) round tables

- **IOTC**: Rishi Sharma, not much contribution intended except perhaps a swordfish component for the whole Bay of Bengal model.
- **Univercity of Malaya**: do not have an Ecopath model. Contribution would be to cross check the estimates of natural mortality. (B) Want to define her contribution better. Possible contribution could be to compile data for natural mortality estimation.
- **Maldives**: Ahmed Shifaz and Khadheeja Ali. (A) (**area 1** on the map) Catch records for past 30-40 years are available. In the past more effort was made on collecting catch records for the large pelagics (skipjack and yellowfin tuna). In recent years work has been done to improve catch data collection on reef fishery and grouper fishery. Since the Maldives has quite substantial amount of catch records and fishery information for the past 5-10 years it would be possible to develop a model with further surveys to gather missing information and oceanographic parameters that are relevant. A model could also be developed to assess the implications of the shark fishery ban on reef fisheries and the coral reef ecosystems. Proposals can me made, but there is limited capacity to carry out the study. (B) An interesting project would be to use Ecospace to model reef fisheries (concentrated in a few reefs only), and the effect on a ban on shark fishing on these ecosystems. A larger scale model could be used to examine the large pelagics fishery.
- **India**: Sunil Mohamed and K K Joshi. (A) Have developed a model of the Indian Gulf of Mannar (20,000 km^2, 33 groups, unpublished; **area 2** on the map). There is an interest in building a model for Palk Bay (Bay shared with Sri Lanka; **area 6**) because it is mostly sea grass habitat and has a good number of dugongs. Two models were developed in the Arabian Sea: NW coast (unpublished, **area 3**) and Karnataka[2] (**area 4**). Finally, a model of the pelagic ecosystem of the Lakshadweep Islands (**area 5**), the northern extension of the Maldives chain is being built. These are coral atolls and have an important skipjack fishery. Data is being collected for the coast of India in the Bay of Bengal but will not consider only one model for this area but 3 areas: Andhra, Odisha, West Bengal (**areas 8-10**). There is no clear way to carry out this research at his time though. (B) There are temporal closures on the East coast, it would be interesting to evaluate their effectiveness and the need for more closures. **It would be very useful to obtain a letter from the BOBLME project to support the work on these areas.** India has a lot of diet studies available on the Central Marine Fisheries Research Institute web site[3] and through Joshi. In the Gulf of Mannar, the issue of MPAs is an issue and could be addressed. This aspect would greatly benefit from collaboration with Sri Lanka colleagues (adding **area 19**). Another issue is the illegal fishing by Indian trawlers in Sri Lanka waters where trawling is banned. Spatial modelling would probably be required to address issues in the Gulf of Mannar. There is also interest in using MSE and social benefit modules.
- **India, West Bengal**: Sachinandan Dutta is working on a model (**area 7**). Would be interested in working on the rest of the Indian coast (Andhra, Odisha) as well.

[2]Mohamed, K.S., and Zacharia, P.U. 2009.Prediction and modelling of marine fishery yields from the Arabian Sea off Karnataka using Ecosim. Indian Journal of Marine Sciences 38: 69-76.
Mohamed, K.S., Zacharia, P.U., Muthiah, C., Abdurahiman, K.P., and Nayak, T.H. 2008. Trophic modelling of the Arabian Sea ecosystem off Karnataka and simulation fishery yields 51, Central Marine Fisheries Research Institute, Cochin, India. 140 p.
[3]http://eprints.cmfri.org.in/

- **Bangladesh**: Rashed Un Nabi and Mohammad Enamuel Hoq. (A) A student has already constructed and published a model of the EEZ[4] (**area 10**). Plan on improving the model by adding bottom and mid-trawlers fleets. Have small scale effort and catches time series 2004 (4 landings sites in 2008, estuary of 5 rivers). Used this data to see diversity of fish caught (used Primer + PEST); all these catches informed SAUP data that are in the report (Zeller et al. 2013, distributed to participants). Have Nansen survey in 1978-80. After 1986, there was no official survey. The department of fisheries had two research vessels from which were derived biomass and MSY estimates (1983-1986). The 2012 model would represent period 1970-2004. Have number of trawlers and total production. (B) The management question would have to be defined further.
- **Myanmar**: Daw Thida Moe and W Aung Win Sei. Have demersal national (plus the Nansen) trawl surveys of all three regions of the coast. It would be possible to make an Ecopath model of the northern section (**area 11**). The two other sections within **area 12** could be eventually addressed later on.
- **Andaman**: Arun Kumar. Doing a model of Port Blair on the east coast of Andaman (**area 13**). Would like to make a model of the EEZ of Nicobar and Andaman. It is possible to obtain survey data, data on mammals, benthos, plankton and others. (B) The management question would need to be defined better.
- **Thailand**: Praulai Nootmorn and Montri Sumontha. (A) Have long-term data from research vessel plus long-term data for commercial and small scale fleets. Data mostly for coastal areas (<100m). Have two types of research vessels, inshore and offshore. There is data for offshore Bay of Bengal (**area 17**). Have more precise data on sharks, especially threshers. (B) Interested in making a model of EEZ (**area 14**). Would be interested in examining the effect of fishery closures. They also have depth, oxygen and temperature map. Interested in modelling the effect of climate change.
- **Malaysia:** Meii Mohamed Norizan: (A) want to do a model of the EEZ in the Malacca strait (**area 15**) and perhaps will overlap with Indonesian waters in collaboration with Indonesian colleagues. Have bottom trawl surveys. (B) Have a preliminary model of the west coast in 2003[5] with 15 functional groups. Have coastal (20-120m) demersal trawl survey 1987-1991. The challenge would be diet compositions (but see India). Would consider inshore and offshore separately; it was suggested to use an Ecospace model with recent data. The management question remains to be better defined.
- **Indonesia**: Khairul Amri and Reny Puspori Ramli. (A)The data available are survey data from 2005 and 2006, which is one year and two years after tsunami. The gear used to collect the data was the fish trawl so that the proportion of demersal fish, pelagic fish and shrimp species are seemingly unbalanced. Interested to build a local model for west coast of Sumatra (**area 16**) but it will need more time. About data that could be contributed to the BOBLME model; the data available for west coast of Sumatra are:
    - Catch rate from trawl data, already converted into biomass data
    - Catch/fleet
    - Phytoplankton biomass
    - Acoustic data : not yet converted into biomass data

[4]Ullah, M. H., Rashed-Un-Nabi, M., and Al-Mamun, M. A. 2012. Trophic model of the coastal ecosystem of the Bay of Bengal using mass balance Ecopath model. Ecological Modelling, 225(0):82-94.

[5]Alias, M., 2003.Trophic model of the coastal fisheries ecosystem of the west coast of Peninsular Malaysia. In: Assessment, management and future directions for coastal fisheries in Asian countries. pp. 313-332, Ed. by G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R. A. Valmonte-Santos, C. Luna, L. Lachica-Alino, P. Munro, V. Christensen, and D. Pauly, World Fish Center, Penang (Malaysia). Vol. 67.

- We intend to give you the copy of survey report in next future (by email), as we presently have the draft report only.

(B) The management question that would be interesting to address is the localised decline in fisheries resources along the coast. An Ecospace model would be useful to address this.

- **Sri Lanka**: Buddhika Dulan Abeyratna and W. N. C. Priyadarshani. (A) Want to make a model of the northeast coast of Sri Lanka (**area 18**) which includes a large estuary. There is already a model published on the coast of Sri Lanka[6] . Have trawl survey for one year (recent), and data for zooplankton and phytoplankton inside the EEZ and outside (one year). Have stock assessment on sea cucumber and lobster. (B) A spatially-explicit model of the northeast coast (Ecospace) would be useful to understand the impact of the river on fish and their habitats. It was noted that an Ecosim model including seasonal forcing would be more useful than separate models for each seasons. Would like to collaborate with Indian colleagues to make a common model (**areas 2 and 19)**.

[6]Haputhandri, S. S. K., Villanueva, M. C. S., and Moreau, J. 2008. Trophic interactions in the coastal ecosystem of Sri Lanka: An Ecopath preliminary approach. Estuarine, Coastal and Shelf Science, 76:304-318.

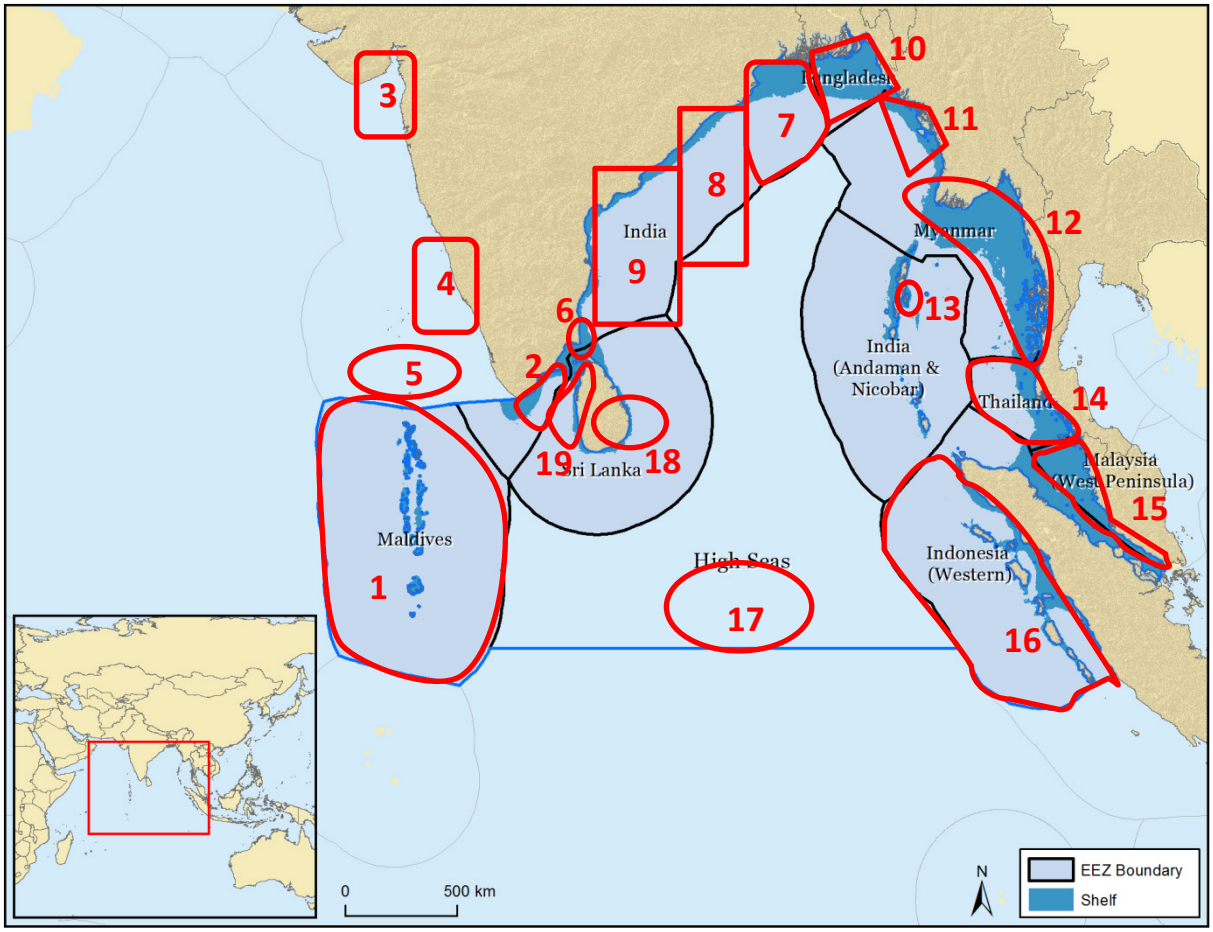

Figure 1. Location of models already published and in progress

1. Maldives, to be built
2. Indian waters of the Gulf of Mannar, unpublished
3. NW coast (Arabian Sea), unpublished
4. Karnataka (Arabian Sea), published
5. Lakshadweep Islands, being built
6. Palk Bay, (Bay shared with Sri Lanka); interest in building model
7. West Bengal, India, being built
8. Odisha region, interest in building model
9. Andra region, interest in making a new model
10. Bangladesh, model published, to be updated
11. interest in building a first model in Myanmar (planned)
12. probably 2 models could be built for these regions of Myanmar
13. model being built for the eastern coast of Andaman; could make model of the whole Andaman coast
14. Thailand, interest in building a model
15. Malaysia, interest in building a model
16. Indonesia, interest in building a model
17. area of high seas data (Thailand) for which there is survey data
18. northeast coast Sri Lanka
19. Gulf of Mannar possible joint project with Indian colleagues

5. Pre-workshop questionnaire

Participants were asked to fill a questionnaire where they stated their level of knowledge about the use of software, assessment techniques, Ecopath with Ecosim and other ecosystem models, fisheries economics and fitting models to data (Appendix 1).

All except two of the 19 participants stated being proficient (moderate and advanced levels) in Excel (17/19) while most (68%) had no experience in R and programming. Most participants had previous experience (limited to advanced levels) with assessments methods: 89% with length-based methods, 79% with age-based methods, and 68% with surplus production models.

Most participants had no or limited knowledge of Ecopath with Ecosim software: 79% for Ecopath, 95% for Ecosim, and 100% for Ecospace. Five participants have used software (Primer, Powersim, Stella, Matlab) to carry on other types of ecosystem modelling and multispecies analysis at limited or moderate levels. Most participants (74%) had no or limited knowledge of fisheries economics. Finally, five participants (26%) stated being proficient at fitting models to data.

6. Workshop evaluation

After the workshop, participants were asked to fill a workshop evaluation to provide feedback and guide planning future workshops. The organisation of the workshop (venue, efficiency, the way it was conducted) was greatly appreciated by the participants (**Appendix I**). Participants' evaluation and comments showed appreciation for the way the material was presented and the attention of instructors to individual needs.

The participants often remarked on the material being presented too fast, and on the need to spend more time on tutorials to fully explore and understand the material. This is not surprising given the depth and the large array of subjects covered during the workshop. Thus, several participants stated they did not feel comfortable yet to build Ecopath model by themselves yet, and most recommended a follow-up workshop on sub-regional models. Nevertheless, Ecospace, a more advanced feature of the software, triggered a lot of interest. Indeed a fair proportion of the sub-regional models that were suggested by participants had a spatial component that would allow answering their management questions. This suggests that covering a large part of the software capabilities was useful to provide a sense of the possibilities.

Several participants recommended follow up workshops and to continue developing the model(s). Sub-regional models were seen as a more efficient way to learn modelling, and if such models are developed they can then be integrated in the regional model (Appendix 4). From the written comments and the discussion with participants, it was clear that for maximum efficiency, the project should continue with the same local experts who received the basic training and will engage into building sub-regional models.

7. Recommendations

- Sub-regional models should be built by local experts and later integrated in the regional models
- Local experts should start working as soon as possible on the sub-regional models
- The regional model will be modified and improved by information that will be contributed by local experts
- Technical support to complete sub-regional models should be available by email with the experts
- A follow-up workshop should be held next spring 2015

On the regional model: It was proposed that the regional model be extended into a spatially explicit model (Ecospace) using national and sub-regional additional information to inform the model. It would be useful if the data announced during the workshop by participants would be made available for the regional model as well as for the sub-regional model, e.g., effort data by country, survey biomass estimates, information on habitat preference based on survey data.

Appendix I List of participants

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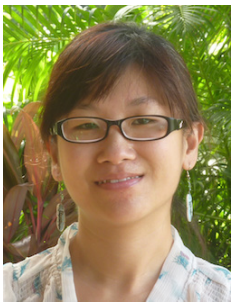

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Appendix II Agenda

Day 1. Monday, 8 Sep. 2014: Ecopath	
08.00 – 09.00	Arrival and registration of participants
09.00 – 10.00	Welcome Introduction of participants (background and experience with EwE) Expectations for the workshop (everyone, please consider and be prepared) Pre-workshop survey (Pre workshop survey.xlsx) Group photo
10.00 – 10.30	**Tea/Coffee**
10.30 – 12.30	Introduction to EwE the approach and software *Demonstration: the EwE software.* Presentations: Modelling marine ecosystems: Lessons learned (Modeling marine ecosystems.pdf); EwE6 introduction (EwE6 Introduction.pdf) Readings: Christensen & Pauly 1992. Pauly et al. 2000. Christensen & Walters 2004. Christensen & Walters 2011.
12.30 – 13.30	**Lunch**
13.30 – 15.00	*Tutorial 1: Build and parameterize an ecosystem model of Anchovy Bay*
15.00 – 15.30	**Tea/Coffee**
15.30– 17.00	*Tutorial 1: continued*

Day 2. Tuesday, 9 Sep. 2014: BOBLME Data and Mass-Balance	
09.00 – 10.00	Summary of Day 1. Questions. Presentation: Ecopath equations (Ecopath equations.pdf)
10.00 – 10.30	**Tea/Coffee**
10.30 – 12.15	Overview of BOBLME Ecopath model (Overview of the Bay of Bengal model.pdf) Model structure (study area, 3 regions, functional groups) Data used for the model construction (fish surveys, Fish base or local studies for growth and diets, oceanographic data, benthos studies) Catch(Zeller 2013 BOBLME_CatchReport_Oct-17-2013.pdf) Fridtjof Nansen (and other) survey data (based on synthesis report) No data for the coasts of India Species aggregation by families Data for 1978-1989, what other surveys are there? What information can you contribute to the model? BOBLME Model Description (Bengal report 27aug2014 net.pdf). *Exploring the BOBLME Ecopath model: Basic input parameters* Biomasses, densities P/B = Z = natural mortality + catch/biomass Pedigree Model database: BOBLME model (BOBLME 5sep2014.zip) BOBLME User Guide (User guide 27aug2014.pdf) BOBLME Model Parameters (BOBLME Appendix 4 net.xlsx)
12.15 – 13.15	**Lunch**
13.15 – 15.00	Presentation: Natural mortality estimation (by Amy Then).Paper link Mass-balance Modelling: introduction; parameters. Presentation: Ecopath parameters (Ecopath parameters.pdf) Presentation: Mass-balancing (Mass balance.pdf) *Tutorial 2: Mass-balancing of ecosystem models*
15.00 – 15.30	**Tea/Coffee**
15.30 – 17.00	*Tutorial 2: continued* Presentation: Network analysis, incl. Mixed Trophic Impacts (Mixed Trophic Impacts.pdf)

Day 3. Wednesday, 10 Sep 2014: BOBLME Model and Ecosim	
09.00 – 10.00	Summary of Day 2. Questions. *Exploring and further developing the BOBLME Ecopath model:* Making sub-regional models (participants): BOBLME model as sum of sub-regional models: suggestion for follow-up workshop Modification of parameters and addition of new data Discussion Participants are invited to contribute expert opinion or data, for biomass estimates, longevity, diets, and any other parameters Information about spatial distribution of large pelagics (tunas, sharks for instance) in the three regions is welcome *File on Widely distributed species: (*Widely distributed species.pdf) Summary of discussion to be corrected by participants: (Possible contributions 10sept2014.docx)
10.00 – 10.30	**Tea/Coffee**
10.30 – 12.30	The foraging arena: Modelling predator-prey interactions. Time-dynamic Modelling; Ecosim; density-dependence and carrying capacity. Fitting to time series. Presentations: Time dynamic Modelling, Ecosim (Ecosim.pdf). Readings: Walters et al. 1997. Walters et al. 2000. Ahrens et al 2012. Walters &Kitchell (2001).
12.30 – 13.30	**Lunch**
13.30 – 15.00	Presentation: Time series fitting and environmental parameters (Time series.pdf). Tutorial 3: Time series fitting
15.00 – 15.30	**Tea/Coffee**
15.30 – 17.00	Tutorial 3: Time series fitting (continued) Demonstration of time series fitting

Day 4. Thursday, 11 Sep. 2014: BOBLME Ecosim, Economics & Spatial	
09.00 –10.00	Summary of Day 3. Questions *Exploring the BOBLME Ecosim model:* *Effort time series* (Ecosim data.pdf): qualities and flaws Biomass time series Catch time series and Stock Reduction Analysis (SRA) Time series fitting of the model: Examination of fitting results and impact on functional groups Alternative fits Implications Impact of different effort time series On the need for more time series Participants are invited to evaluate estimates of fishing effort time series and provide advice on additional information Monte Carlo simulation results Monte Carlo runs: evaluate input parameter uncertainty MSY estimation: trade-offs between species (ecosystem MSY < sum of single species MSYs) Potential future scenarios Readings: Reconstruction of effort time series for India (bhathal_brajgeet 2014 thesis.pdf) BOBLME model times series (download from file list below: time series 3dec2013minimal.csv ; time series 3dec2013minimal.csv) Readings: MSY, Walters et al., 2005
10.00 – 10.30	**Tea/Coffee**
10.30 – 12.30	From sea to consumer: Modelling food webs and the economic value chain Presentation: Economic and social analysis in EwE (EwEconomics.pdf) Readings: Christensen et al. 2011. Christensen et al. 2014. *Exploring the BOBLME Ecopath model: economic and social aspects *)*
12.30 – 13.30	**Lunch**
13.30 – 15.00	Spatial Modelling; Introduction to habitat capacity Modelling, zoning & MPAs. Presentation: Spatial Modelling in EwE (Ecospace.pdf) Readings: Walters et al. 1999. Christensen et al. 2009. Christensen et al. *in press.*
15.00 – 15.30	**Tea/Coffee**
15.30 – 17.00	*Tutorial 4: Spatial Modelling of Anchovy Bay*

Day 5. Friday, 12 Sep. 2014: Ecospace and further development	
09.00 – 10.00	Summary of Day 4. Questions *Exploring the BoB LME Ecopath model, preparations for spatial Modelling* Presentation (MSE.pdf) of Management Strategy Evaluation (tutorial)
10.00 – 10.30 10.30 - 13.30	**Tea/Coffee** (with photos of participants) Demonstration of Management Strategy Evaluation Presentations from participants about existing, ongoing, or potential sub-regional models from BOBLME area What's next: future work on ecosystem Modelling in the BOBLME: model development and follow-up workshop? Written evaluation Closing
13.30 – 14.30	**Lunch**

Appendix III Pre-workshop survey

Survey of state of knowledge and experience of the 19 participants				
	Experience			
Software	None	Limited	Moderate	Advanced
Excel		2	13	4
R (Splus-like)	13	4	1	1
Programming	13	4	1	1
Assessments				
Age-based assessment	4	8	4	3
Length-based assessment	2	6	7	4
Surplus production, a.o.	6	7	3	3
Ecopath with Ecosim				
Ecopath	10	5	4	
Ecosim	11	7		
Ecospace	17	2		
Other ecosystem models				
Type:[a]	14	1	4	
Fisheries economics	10	4	5	
Other				
Fitting models to data	8	6	4	1
[a] types mentioned are Primer, Powersim, Stella, Matlab				

Appendix IV Teaching and workshop evaluation form

		Agree		Disagree			
The instructors	Strongly	Mildly	Neutral	Mildly	Strongly	no answer	Total
	5	**4**	**3**	**2**	**1**		
1. Presented material in a clear and understandable way.	13	3	1			1	18
2. Presented material in an interesting way	14	3		1			18
3. Were receptive to questions	13	4				1	18
4. Stimulated participants to think	11	7					18
5. Were considerate of participants individual requirements	13	2	1	1		1	18
6. Workshop was conducted efficiently	14	4					18
7. Workshop was efficiently organized by BOBLME	17	1					18
8. The venue was a good choice for the workshop	16	2					18
9. Participants can now use EwE with confidence	5	9	2	2			18
10. A follow-up workshop on sub-regional models is recommended	17	1					18
Sum	**133**	**36**	**4**	**4**	**0**	**3**	**180**
Comments, suggestions, feedback, critique, ….							
e.g. The session on ... Was of most interest to me...							
e.g. I did not like the section on ... (say why)							
e.g. The material was presented too fast/slow							

Summary of the comments

Positive comments

About the most interesting sessions:

The most interest to me was Ecosim, economics, and spatial

The most interesting to me was Time series, Ecospace, MSE

The most interesting session was Ecospace (3)

I was most interested in all sessions (3)

About the material presented

Material was great.

Many thanks to BOBLME, Chris, Villy, Sylvie, Nishan, Sucharat and everyone for the wonderful training.

This is my first international workshop. I had a wonderful experience with the experts.

Villy and Sylvie had great presentations

The material was presented at the right pace (2)

This 5 day workshop was fantastic. I did not expect that this program will be this productive and impressive.

I think the organisation of this workshop is like a well-oiled machine: communication of schedule of program, the reading outline, the logical flow of events, the inclusion of (manageable) tutorials, etc. very well put together. Thank you! Overall, this workshop has been very useful to integrate and bring together experts from different regions. Hopefully this will translate into a long-term collaboration.

Usefulness for the BOBLME and personal development

This workshop is very interesting and useful for ecosystem in the Bay of Bengal.

Good start for BOBLME Ecopath

This workshop is very interesting and useful for ecosystem in the Bay of Bengal.

This training workshop is very interesting for me. In my country, Myanmar, there is no research vessel to conduct marine fisheries research work. So we have to collaborate and join to conduct. We need also such training for human resources. I, Myanmar () would like to build the model for our coastal region and then liked to use EwE very well.

Personally, I feel this program opens up opportunity for me to develop my career in fishery research aspect.

The workshop motivated me to start sub-regional model using data I have.

Critical comments

On the pace and length of the workshop

Some of the materials were presented a bit fast (2)

The material was presented too fast, “ingestible” (however)

5 days is a short time to learn the whole thing

Deliver it in a week is too fast. I can understand a part, but need more time to understand how to use the software. Currently, specially to build an Ecosim model.

Country specific long-term (7-15 days) training would be more realistic

Should change the program to may be have more time for our exercise and less on lectures.

I only have one suggestion that is I would like to go through tutorials at slower pace to understand better why we are putting the numbers, what the numbers shows, as even trying to find a button/tab was a bit challenging.

On the lack of understanding of the software:

I need more experience run the model. I am also a bit confused on how to estimate Ecopath parameters.

Overall, the workshop was fine. However, I struggled to see some results/estimates sometimes. I don't know whether it was due to compatibility of my computer capacity with the model or any other reason. As such, I had trouble following some parts so it is better to accompany with all participants next time.

The first tutorial was the most interesting as it was easier to understand; the session on arena theory was interesting as it explained the science behind the model. There were lots of interesting things which I personally could not understand. It could be mostly because of my lack of experience in the stock assessments. I wish we could have spent more time working on the tutorials on our own (may be a manual for working out the tutorials could be provided).

Other

As a first-time participant, a little more background on BOBLME and the history timeline/chronology of dates, progress and objectives would be helpful prior to coming to the workshop. I was not sure if I will be a passive participants (i.e. be trained) or whether some input will be required of me (maybe you did communicate this and I missed the memo?).

Recommendations

On the need of follow up workshops

BOBLME should "organise" more workshops like this in the future.

Please consider conducting follow up EwE workshops in subregion countries with support from BOBLME/FAO/UNDP to make more familiar and useful for the scientists working on the ecosystem based fisheries management. I am "recollecting" the way in which FAO/UNDP workshop in India which made "familiarity" in the use of Fisat in stock assessment.

Follow up is required to complete this project successfully, not only in terms of workshop and meeting but also by communication via mail.

Follow up workshop is recommended with the same participants; otherwise you have to start from the beginning

Hope the follow-up workshop would happen and experts from UBC get to evaluate them.

CMFRI have got data and manpower on fishery biology and stock assessment will benefit better by workshop.

More workshop on EwE and more technical support of each country

If possible, please continue with advance workshop

On future developments

Strong recommendation for further development.

Spatial modelling in BOBLME is the next step.

In my view it would have been better if sub-regional models were developed first and been integrated to create a whole model of the BOBLME. But now, since time is short, and we have a preliminary model of BOBLME, and the sub-regional models being developed later; we could try and integrate information from the sub-regional models into the BOBLME model.

I would propose the workshop on the BOBLME EwE by using Thailand data set, catch, effort, CPUE (long-term data) from research vessel and landing survey of commercial and small-scale fisheries.

Using country specific/ sub-regional data in future raining will improve participant's efficiency.

Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand are working together through the Bay of Bengal Large Marine Ecosystem (BOBLME) Project to lay the foundations for a coordinated programme of action designed to better the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries.

The Food and Agriculture Organization (FAO) is the implementing agency for the BOBLME Project.

The Project is funded principally by the Global Environment Facility (GEF), Norway, the Swedish International Development Cooperation Agency, the FAO, and the National Oceanic and Atmospheric Administration of the USA.

For more information, please visit www.boblme.org

Food and Agriculture Organization of the United Nations

gef

SWEDEN

Norad